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R&D work for Superconducting Magnet for Future Accelerator Applications

R&D on superconducting magnets for accelerator applications has been conducted at KEK for more than 40 years. One of the major accomplishments is the development and the construction of LHC insertion quadrupole MQXA [1], which has the highest conductor field of 8.6 T. After the successful development of MQXA and their successful operation, KEK is now developing the large aperture beam separation dipole magnet D1 [2] for HL-LHC. KEK has also succeeded developments of superconducting accelerator magnets for its own projects such as superconducting beam line for T2K neutrino experiment facility [3] and developments of solenoid magnets for detector and muon experiment program such as COMET [4] and g-2/EDM [5].

Although all of these project-based magnets were developed with the NbTi superconductor, R&Ds of magnet technologies with advanced superconductor such as A15 or HTS have been conducted as well. For A15, Nb_3Sn conductor development, aiming for the Future Circular Collider (FCC-hh) proposed in Europe, is now being conducted in collaboration with CERN, Tohoku Univ., Tokai Univ., NIMS, and two Japanese industrial partners [6]. For HTS developments, US-Japan collaboration is formed by KEK, Kyoto Univ., LBNL, and BNL for high field and high radiation environment applications [7]. The quench protection as well as effects of shielding current in the HTS conductors are also studied.

Next mid-term goal of the KEK will be developing high field radiation hard superconducting magnet technologies for future accelerator applications such as future energy-frontier hadron colliders and high intensity proton drivers in extension of these collaborative works.

One of the R&D targets can be the beam separation dipole (D1) for FCC-hh (Future Circular Collider hadron-hadron) that is 12 T 100 mm diameter aperture dipole magnet. Although the magnet field is lower than the anticipated FCC arc dipole magnet field of 16 T, the large aperture results in higher force in coil. Since, mechanical stress management in the magnet structure as well as stress durability of the Nb_3Sn conductor can be the important factor, study on magnet structure and mechanical properties of the conductor will be the major R&D target. For the mechanical properties of the conductor, measurement of the I_c dependence with various mechanical stress can be performed. A development of mechanically strengthened Nb_3Sn conductor can also be performed since such studies were already performed by some of the collaborators such as Tohoku Univ [8]. Since the magnet will be placed in relatively high radiation area, radiation hardness of the magnet should be a key issue. The study on radiation hardness as well as mechanical durability in various operation cycles for the impregnation resin, in case of wind and react coil, should be performed. The other insulation material technologies such as sol-gel type of inorganic materials may be studied as well. Ultimate goal of this R&D may be to construct model dipole magnet with acquisition of appropriate external funds.

For the HTS development, a near term target for KEK may be the development of radiation hard HTS magnet technologies for high intensity muon production solenoid. At J-PARC Material and Life Science Facility (MLF), a new proposal to build the second target station has arisen. For this target station muon production solenoid of about 1 T central field is directly attached to the 1 MW target that produce both muon and neutron. The facility aims to produce 50 to 100 times more muon than the current MLF muon source that results in world leading intense muon source. The solenoid requires high radiation hardness and also high reliability on quench protection. The currently on-going US-Japan collaboration obviously benefit to this project and should be extended. The ultimate goal of this R&D is of course realization of the second target station with appropriate budget supply from Japanese government.

For further future, the above two R&Ds can be extended to the R&D of 16~20 T accelerator magnet, by combining the 12 T Nb_3Sn large aperture dipole with 4~8 T HTS (or Nb_3Sn) insertion coils. For the HTS part of the development not only high field applicability is required but also development of high current cable conductor should be performed. The current US-Japan collaboration already included the study on the high current cable development and the effort should be continued. In the collaboration with Kyoto Univ., extensive studies have been performed on influence of shielding current in HTS tape conductor [9]. The work will be essential to develop the magnet that can achieve the accelerator field quality. For that sense, the extension of the collaboration should be essential to the R&D. Since the current study on both Nb_3Sn and HTS magnet technologies include the radiation hardness studies, the results of the R&D should lead to the high field, high radiation hard accelerator magnet technology that required for FCC insertion quadrupole magnets.

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